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Numerical Analysis on Microwave Beam Interaction with Ionospheric Plasma in Space Solar Power System

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In the Space Solar Power System (SSPS, Fig. 1), solar energy is converted to microwaves and transmitted to the ground. In order to study the feasibility and the implications of SSPS, we conducted several rocket experiments of microwave power transmission (MPT) in the ionosphere. In the rocket experiments, we found that electrostatic plasma waves were excited around the local plasma frequency in association with intense microwave emission. This plasma interaction may cause the loss of microwave energy. Theoretical analysis showed that the excited electrostatic waves are due to so called three-wave coupling. In order to study the nonlinear wave-wave-particle interaction associated with the microwave energy transmission in space plasma, we performed numerical simulations with an electromagnetic PIC (Particle-In-Cell) model. In the simulations, we focus on the spatial and temporal evolution of the three-wave coupling as well as the dependence of the interaction on the amplitude of the pump electromagnetic waves.

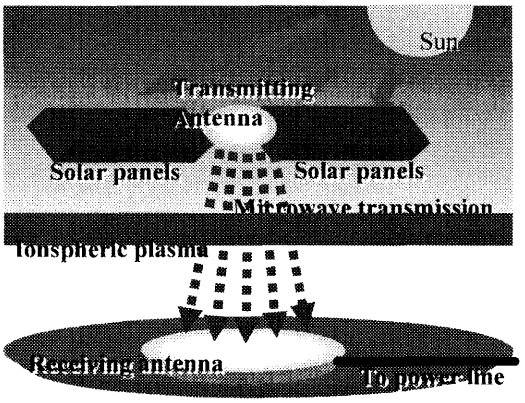

Fig.1 SSPS (Space Solar Power System)

In the simulation space filled with magnetized plasma, we emit intense electromagnetic waves from an antenna located at one edge of the simulation system. When the electromagnetic waves are intense enough, a three-wave coupling occurs, which is the consequence of a nonlinear interaction between forward and backward propagating high-frequency electromagnetic waves and a low-frequency electrostatic one propagating in the forward direction. The results show that a fraction of the electromagnetic waves emitted from the antenna is backscattered by the background plasma, which induces electrostatic waves at the plasma frequency (fig. 2). Since the electrostatic waves cause electron heating, the local plasma condition changes and the three-wave coupling ceases.

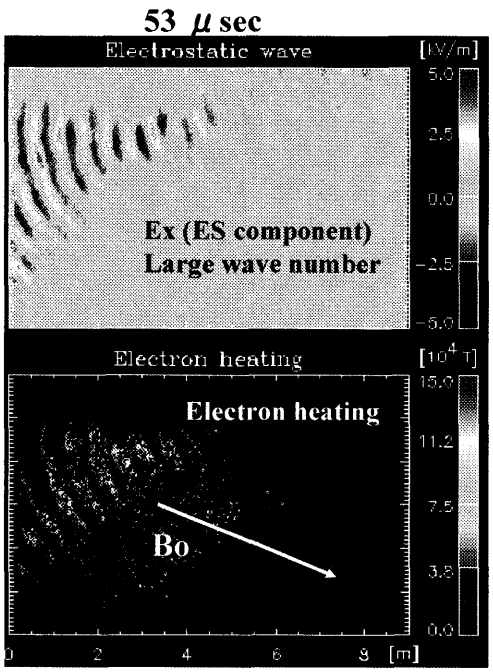

Fig. 2 Two dimensional simulation results which show low frequency electrostatic wave excitation (upper panel) and associated electron heating (lower panel).

We also found that the nonlinear process can be affected by the local electron heating by the excited electrostatic waves because the characteristics of the excited waves depend on the electron temperature. When the geomagnetic field is perpendicular to the microwave propagation, electrons are most heated because the excited electron cyclotron harmonic waves are less affected by the electron temperature.

REFERENCE

Usui, H., H. Matsumoto, and R. Gendrin, Numerical simulations of a three-wave coupling occurring in the ionospheric plasma, Nonlinear Processes in Geophysics, Vol.9 No. 1, 1-10, 2002.